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York 372 cases, with 1 death; in Oregon 213 cases, with 1 death; in Maine 150 cases, with 1 death. In 21 States a total of 3,166 cases were reported without a death.

The largest numbers of cases were reported in the following States: Utah 707, Minnesota 703, Washington 481, New York 372, Indiana 348, Wisconsin 284, Illinois 267, Michigan 250, Oregon 213, Ohio 178, Texas 176, Maine 150, California 126, Virginia 115, Oklahoma 113, Alabama and North Dakota 111 each, Vermont 110, Pennsylvania 106. The smallest numbers were reported as follows: Wyoming 2, Connecticut and New Jersey 3 each, District of Columbia 7, Colorado 15, Florida 17, Maryland 20, Massachusetts 37, Arizona 45, Kansas 55, North Carolina 57, Montana 69, Iowa 81, and South Dakota 90.

Smallpox was also present in States not enumerated in the table, but information regarding the number of cases occurring in them has not been available.

During the first quarter of 1912 there were reported 8,850 cases of smallpox, with 81 deaths; during the second quarter 5,734 cases, with 53 deaths; during the third quarter 2,070 cases, with 58 deaths.

The reports from Massachusetts, Minnesota, and New York for the fourth quarter of 1912 gave the vaccination histories of the patients in detail as follows: In Massachusetts, of 37 cases notified 1 of the patients had been vaccinated within 7 years preceding the attack, 1 had been last vaccinated more than 7 years preceding the attack, 25 had never been successfully vaccinated, and in 10 cases the vaccination history had not been obtained. In Minnesota, of 703 cases notified 12 of the patients had been vaccinated within 7 years preceding the attack, 44 had been last vaccinated more than 7 years preceding the attack, 550 had never been successfully vaccinated, and in 97 cases the vaccination history had not been obtained. In New York, of 372 cases notified none had been vaccinated within 7 years preceding the attack, 29 had been last vaccinated more than 7 years preceding the attack, 204 had never been successfully vaccinated, and in 139 cases the vaccination history had not been obtained.

FUMIGATION OF VESSELS FOR THE DESTRUCTION OF RATS.

By S. B. GRUBBS, Surgeon, and B. E. HOLSENDORF, Pharmacist, United States Public Health Service.

The fumes of burning sulphur, which have for so many years been used empyrically by practical sanitarians to arrest the advance of epidemic diseases, remain to-day the most convenient and efficient fumigant. The efficiency of sulphur fumigation rests on its well demonstrated germicidal qualities, its safety, and the ease with which it may be applied.

For the destruction of rats on board of vessels, as an antiplague measure, the burning of roll sulphur in iron pots, has not been displaced by any of the more recently proposed methods. Hydrocyanic acid gas is rarely used on account of the danger to human life, while funnel gases require an expensive apparatus and are practical only for large spaces, such as the holds of vessels. The technique of sulphur fumigation, however, varies much at different ports, from the most careful treatment of every part of a vessel to the routine burning of a few sulphur pots in a vessel's hold, a procedure of little value and giving a false sense of security.

We believe that if fumigation is necessary all parts of the vessel should be sulphured at the same time, including all compartments above deck from which the presence of rats can not be absolutely excluded, as well as the holds; that the most careful preparation of a vessel is necessary; and that fumigation of the holds alone, especially if containing freight, is of little value, if not actually harmful, as it may drive rats to the decks whence they may more easily go ashore.

The Report of the Board of Health on Plague in New South Wales, 1907, gives the following instance, showing the danger from vessels and the difficulty in ridding them of rats:

> The Adelaide Steamship Co.'s *Innamincka* runs from Melbourne, Victoria; in the south to Cairns, Queensland; in the north carrying general cargo and passengers; going south her cargo consists chiefly of sugar and bananas. She calls at Sydney, New South Wales, and at Brisbane, Makay, Townsville, Bowen, and Cairns, Queensland. She is empty only at Melbourne and at Cairns, and at these ports is fumigated for destruction of rats. On the voyage now spoken of the *Innamincka* reached Sydney May 21 from Cairns, where she had been fumigated as usual, and sailed again for Melbourne on the 22d. During the night of May 21 a rat catcher of the intelligence staff set many traps on board and found the next morning that 18 live rats had been caught; in addition he found one dead rat lying beside the cages. The live rats were kept for some time and remained healthy, but the dead rat was found to be infected with plague. The vessel having sailed in the meantime, Melbourne was warned by telegraph. On arrival there on the afternoon of May 24 the vessel was arrested, anchored in the stream, and fumigated with her cargo on board; the next morning hatches were opened, she was taken alongside, and discharge of cargo was begun. In the course of discharging 160 carcasses were found.
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> Having been emptied, she was placed under sulphur a second time on the afternoon of May 25, and when hatches were again opened, on May 26, 164 more carcasses were turned out. After examination a number of these carcasses were declared to be plague infected. The ship was then thought to be rid of rats. She took on eight to nine hundred tons of cargo and sailed for Sydney as usual on her return voyage to the north. On arrival at Sydney, May 29, she was searched by the intelligence staff, under supervision of the chief sanitary inspector, and 41 live rats and 22 carcasses were collected. Consequently all of the cargo aboard was ordered out, and during the unloading 35 rats were killed and 34 more carcasses were found. The ship was then placed under sulphur for 12 hours, with the result of finding 509 carcasses of rats, 12 of mice, and 2 rats alive, though dying. Nevertheless live rats were still heard; the reason was afterwards found to be existence of a hole of communication between a forward hold and a cross bunker in which some rats had found protection from the fumes among the coals. It was thought necessary, therefore, to empty all the bunkers; this took 36 hours of continuous work. Then the after part of the vessel with the engine rooms and stokeholds were first filled with sulphur fumes, after which a second fumigation

of the forward holds commenced. After this 70 carcasses were found, but no live rats, and it was at length possible to say that no rats, alive or dead, remained on board. On June 3 she was released, and, after loading, pursued her voyage. Altogether 734 rats were delivered at the board's laboratories on or after May 29, of which about 160 were putrid; 70 of them were examined bacteriologically, being selected from the batches successively brought in, and including some of the putrid carcasses; 44 of these yielded positive films, and from 4 of them positive cultures of *B. pestis* were recovered.[1]

The above citation, with its bewildering refumigations, each yielding more rats, warrants a review. Note that in all, five fumigations were done before the rats were exterminated, that 1,077 rats were found and that out of a small proportion examined, 5 were positively and many more probably plague infected.

Hobdy, of the United States Public Health Service, reports finding 310 rats in a vessel of 260 tons, 525 in another small vessel, and 1,700 in a larger but comparatively new steamer. He also reports that of 30 oil steamers fumigated every one yielded rats from the living quarters.

From our own observations at San Juan, Porto Rico, in 1912, the following instances are instructive:

1. June 20. Steamship *Ponce,* empty. After fumigation all night with 2 per cent SO_2 gas, two live rats were seen, one in a pipe casing in hold No. 3 and the other in a pile of dunnage in hold No. 4. Refumigation of these holds after proper preparation yielded two rats. This demonstrated that a prolonged exposure to 2 per cent gas in an empty hold will not always kill a rat if he can find any protection, hence all such protection must be done away with. Here it was a question of dunnage, or lumber used to keep bags of sugar away from the sides of the vessel, to avoid "sweating." This was disposed of by piling it on frames along the side of the holds about 3 feet above the floors or decks, and knocking down same after fumigation to be sure that no rat had climbed up to them.

The pipe casings and bilges that often have openings large enough for a rat, but admitting but little gas, were thereafter always opened up by having sections removed. On account of the damage this necessarily caused, as well as the labor involved, the steamship companies were requested to include in the changes recommended the making of certain panels in these places, which could be easily taken out or opened on hinges.

2. June 22. Schooner *Isabela,* empty, 34 tons register, was fumigated by burning 1 pound of sulphur per ton register, or 10 pounds to 1,000 cubic feet. The sheathing or "skin" was left in place. The fumigation yielded 15 rats, but on cleaning up, one live rat was seen escaping behind the sheathing. Enough of this planking was removed to allow a free circulation of gas, the vessel was again

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[1] This very instructive report was brought to our attention by Dr. Charles V. Chapin, superintendent of health, Providence, R. I.

fumigated, and five more rats were found. This proved that the sheathing of sailing vessels is able to protect rats from death even when some five times the prescribed amount of sulphur is used, and from that time we either removed an occasional plank or required the owners to permanently close all openings.

3. June 26. Steamship *Coamo*, empty. Eight rats were found in the iron coverings of the steam pipes that lie on the main deck and four in the wooden boxing of the ship's telegraph. One rat was found under a bin on the main deck, and, escaping, ran direct to the iron pipe covering. After fumigation, 2 rats were found in the main dining saloon, 15 rats in the forecastle—which includes third-class quarters—and 2 in the storeroom aft. This shows how many rats may hide in places usually not molested, even when the upper parts of a ship are fumigated, and caused us regularly to take up pipe coverings, open the boxing of ship's telegraph, and empty and move all bins on deck.

4. July 18. Schooner *Henry F. Kruger*, empty, was fumigated all night, over one-half pound of sulphur to gross ton register being used. On shaking down the sails during final cleaning up a rat escaped from the jib. The second fumigation, done at once, yielded two rats.

5. July 28. Steamship *San Juan*. Before fumigation one rat was found under a box containing flags on the upper deck, and another behind a vegetable bin on the main deck; additional proof that rats may and do remain on deck, hiding easily in places usually not disturbed in the ordinary fumigation.

6. August 5. Steamship *Coamo*. The third fumigation in six weeks yielded one rat only, viz, in the first-class toilet room. This shows either that complete deratization of the living quarters may be as difficult as of the holds or that new rats coming on board may remain in the upper parts of the ship.

7. August 7. Steamship *Santurce*, freighter. Fumigation yielded rats as follows: Four from potato bins on deck, forward; 1 from deck, aft; 2 from cabin bathroom; 1 from storeroom, aft; 4 from the holds; 11 from dunnage and rubbish on deck, drowned out by water from the hose.

Observations 6 and 7 prove one of two things: Either the previous fumigations did not kill all the rats and the proportion of those surviving was much greater in the upper parts of the vessel, showing that they not only are present but that it is much more difficult to kill them here than elsewhere, or that new rats coming aboard remain for the most part above deck and go to the holds only later. The hiding of the rats in the loose material on deck emphasizes the necessity of inspections and of excluding rats from every possible cover.

8. August 12. Steamship *Carolina.* The third fumigation yielded 10 rats from the living quarters and only 2 from the holds, which corroborated the conclusions previously drawn.

9. August 9. Steamship *S. V. Luckenback,* second fumigation. The galley aft was fumigated for seven and a half hours with 4½ per cent sulphur gas. On cleaning up, a rat was heard wheezing and running about in a wooden partition. As he could not be caught, some of the tongue and groove siding was removed and the galley refumigated, which yielded five rats.

There are many vessels that have old wooden partitions or other structures that may harbor rats through a long and severe fumigation. Until the necessity of doing away with these—that is, rat proofing vessels—is recognized by shipowners, they must be opened up at each fumigation, if fumigation is to be efficient and insure safety.

10. August 21. Steamship *Julia Luckenback,* second fumigation, rats found as follows:

Seventeen in living quarters and storeroom; 7 between ceiling and deck in staterooms; 1 in forecastle; 1 in deckhouse, aft; 1 in lazaret; 6 in holds.

Here we see again that either one fumigation killed nearly all the rats in the holds but left many elsewhere, or that rats came aboard and remained above decks. If the first is correct, the routine that we recommend, severe and laborious as it is, is none too strict; if the second is correct, the upper structures of a vessel from plague-infected or suspected ports are more dangerous and need more careful fumigation than the holds, because rats getting aboard remain there easily and from above may more easily get ashore at a clean port.

Having concluded from these observations that the greatest care as to details is necessary for the proper fumigation of any vessel, a few simple experiments were made to ascertain what per cent of sulphur dioxide was the best to use.

It is well known that if a rat in a cage is exposed to comparatively weak sulphur fumes, it will die, but if given a chance to protect himself the results are different, and in judging the results of experiments it must always be remembered that the rats are always at a disadvantage, being in a strange place, and confused and debilitated by recent confinement. In this connection it may be well to recall that the United States quarantine regulations prescribe, for the fumigation of empty vessels for the purpose of killing rats, "the simultaneous fumigation with sulphur dioxide gas not less than 2 per cent for six hours' exposure," and states that "an atmosphere containing 4.5 per cent can be obtained by burning 5 pounds of sulphur per 1,000 cubic feet of space."

EXPERIMENTS ON SHIPBOARD.

No. 1. Two rats were placed in a box about 12 feet long by 8 inches square, closed at one end by wire netting only. This was to imitate a pipe casing. After 13 hours' exposure to 4.5 per cent gas in the hold of a steamship, both rats were dead.

No. 2. Three rats in a box 7 by 4 by 1 feet, having many cracks and half full of pieces of board, to imitate a pile of dunnage. After an exposure of 18 hours with 4.5 per cent gas in hold, all rats were dead.

No. 3. One rat was placed in a basket of onions, about 36 by 18 by 18 inches; this was covered with wire gauze, and placed in cargo of onions to be fumigated. Six pounds of sulphur per 1,000 cubic feet were burned, exposure 6 hours, after which the rat was dead.

No. 4. Three rats in large wire trap half full of cotton waste and wrapped in two layers of canvas. After 15 hours' exposure to 2.5 per cent gas all rats were dead.

EXPERIMENTS ON SHORE.

These were made in a small wooden building of one room containing 722 cubic feet. It was pasted up with heavy manila paper in order to make it nearly gas tight.

No. 5. A quantity of loose boards to represent dunnage was piled up at one side of the room. Two rats were liberated in the room and 1.6 pounds of sulphur burned in a manner to give the most efficient fumigation. This is sufficient to generate 2 per cent sulphur dioxide in this room. It was opened after six hours and both rats were found alive and in good condition, but as pasting was not completed at time of experiment and considerable leakage was noted, the leaks were carefully sealed, and the experiment was repeated.

No. 6. Same time, same amount of sulphur and rats as above. One rat was alive and in good condition; the other dead and part of tail eaten.

No. 7. Two pounds of sulphur (2.5 per cent sulphur dioxide). Imitation pipe casing with one rat, as in experiment No. 1, and two fresh rats were liberated in the room with pile of boards, as before. Exposure, six hours. All rats were alive and unaffected, apparently, but as a small amount of the sulphur had not burned the experiment was repeated.

No. 8. Same as above, except that but one rat was loose in room. Result, rat in pipe casing dead, one in room alive.

No. 9. Same per cent gas and time as Nos. 7 and 8. Two rats liberated in room with dunnage. One of these rats had been through experiments 7 and 8 and was still lively and well, but new rat was dead and badly bitten, possibly killed by the old rat.

No. 10. Same room and dunnage. One rat in imitation pipe casing and one loose; 3 per cent sulphur dioxide; six and a half hours' exposure; both rats dead.

It will be very evident, then, that fumigation of the holds of vessels with cargo by burning sulphur will rarely destroy all the rats in that part of the ship and that if this procedure is resorted to it should be considered as a fumigation of the cargo only and that the vessel must be again fumigated empty if it is desired to make it rat free; furthermore, that it is necessary that fumigation be done simultaneously in all compartments and with liberal quantities of sulphur. We believe it is best to use 4.5 per cent gas—5 pounds of sulphur to 1,000 cubic feet—for 7 hours in the living quarters and engine room, which can not be closed overnight without hardship and delay, and to use 3 per cent sulphur dioxide in the holds and similar spaces with an exposure of at least 12 hours. As the pots are usually all lighted before noon, this arrangement allows the crew to sleep indoors that same night and engineers to be getting up steam ready for departure as soon as the pots are removed from the holds the following morning.

ROUTINE OF FUMIGATION.

The following gives the more important details of the procedure as followed at San Juan, Porto Rico:

A circular is handed to the captain of each vessel that will eventually require fumigation, directing him (1) to give timely notice of the hour when he will be ready for fumigation; (2) where to anchor; (3) to have all compartments clean, as empty as possible, and open, and insisting that this means every inclosed space from the hold to the smallest locker; (4) to have fires drawn or banked; (5) to have canvas ready to batten down, including main funnel, gratings over engine room, and any other opening that can not be tightly closed; and (6) to have sections of pipe casings and floors in the holds and of telegraph and pipe coverings on deck removed, unless these have been fitted with hinges.

At the arranged hour a 10-ton lighter containing the necessary paraphernalia, viz., pots of various sizes with sulphur, washtubs, etc., is towed alongside.

While the fumigating crew (eight men) are hoisting these articles on deck a preliminary inspection of the entire vessel is made by the fumigating officer or foreman to ascertain the structural peculiarities of the vessel and its general condition. The blue prints of the vessel are examined to get the cubic capacities of the holds, engine room, fireroom, bunkers, and other compartments. Where these capacities are not shown on the charts they are obtained by taking actual measurements.

In the holds the dunnage is piled or slung up entirely free from the floor, so that it affords no hiding place for rats. The limbers (planking boards) over the bilges are removed, so that the fumes may circulate freely under the sheathing. The sounding and bilge-pipe casings are removed in part, so that the fumes may penetrate these parts. In the lazarets and forepeaks, where the mates' and boatswains' stores are kept, it is necessary to have most of the ropes, canvas, etc., removed. In moving any stores to the deck a careful watch for rats must be kept. In the provision storeroom all open stores and articles likely to be injured by sulphur are inspected and ordered to be removed to the decks. The same is done with similar articles in the living quarters, dining rooms, social hall, etc.

Prior to the lighting of the pots the chief fumigator makes a personal examination of all parts of the vessel to see that everything is in readiness for efficient and safe fumigation, after which the lighting is done by two men, followed in every case by the chief fumigator as a check.

Engine room, bunkers, and shaft alley are given 7 hours' exposure to 4½ per cent gas, which requires banked or drawn fires for a period of at least 10 hours. The living quarters on the main deck, the galleys, forecastle, second cabins, etc., are given the same amount and time.

The staterooms on the promenade and hurricane deck are not fumigated, as a rule. Instead they are minutely inspected to make certain they harbor no rats and that there are no rat holes, and, if satisfactory, are closed during fumigation of other parts.

The holds are given an exposure of 3 per cent gas for 12 hours or more.

During fumigation a careful inspection is made of all deck paraphernalia, including rope lockers, life-preserver lockers, fire-bucket racks, telegraph, pipe, and steering-gear casings, fresh vegetable and potato bins, furled sails, lifeboats and rafts, for the purpose of finding and destroying rodents. Rats have been found in practically all of the places mentioned above.

After the fumigation a minute inspection is again made of the entire vessel and rats are gathered. Everything that was left in the living quarters, galleys, storerooms, etc., is moved, and in the holds the dunnage, that had previously been slung up, is torn down and examined. Finally decks are washed down, if littered.

To many who have had experience in quarantine work, as well as to the layman, the minute care which is here prescribed may well seem impossible of execution. They may remember the delay and confusion that has resulted often, on account of the most ordinary quarantine procedure, such as a muster of all hands, and dread to attempt a general clean-up; and it is true that an occasional fumigation, at a station where the men are not trained for this particular work, must result in slack work or a demoralization requiring time and patience to overcome. When fumigation is being done regularly, as at San Juan, P. R., during the summer of 1912, a system may soon be evolved that will work smoothly, efficiently, and with little delay, doing everything that has been given above as necessary.

The essentials of this system are:

First, obtaining the active cooperation of the shipping interests, keeping them posted as to exactly what they must do and when, issuing them frequent general circulars and letters, and through them instructing the captains of vessels and others.

Second, the careful selection of a fumigating crew with a foreman and assistant. These men should be above the average, should be well paid and cared for, and should be given ample time off as a return for working under high pressure, which should be always expected.

Third, a standard having been set and instructions having been given a vessel, no relaxation should be allowed, especially on account of objections made, that all may know that active cooperation will save more time than protests.

Fourth, a record should be kept of the detail of each fumigation—preferably a card system—and each record checked up by the responsible head of the quarantine station before filing.

Of these requisites for rapid and efficient work, the training of a crew for this particular work is perhaps the most important, and it is to be regretted that such crews seldom exist except in times of emergency when they must be trained under the most trying circumstances of confusion and delay, only to be disbanded as soon as the epidemic has subsided.

Not only should the regular and subordinate officers in charge of quarantine work, or liable to be called upon at any time to do this work, be thoroughly familiar with the best methods of fumigation, but some fixed standard should be set and officially recognized so that the certificate stating that a vessel has been "fumigated" will mean a definite thing and not as now anything from burning a few pots of sulphur in a vessel's hold to the most thorough deratization, such as we believe was done in the outgoing quarantine work at San Juan, P. R., during the epidemic of plague, now happily at an end.